Prescribed Fire - A Cost Effective Control for White Pine Cone Beetle

D. D. WADE
U.S. Forest Service
Macon, Georgia

G. L. DEBARR
U.S. Forest Service
Athens, Georgia;

L. R. BARBER
U.S.Forest Service
Asheville, North Carolina

E. MANCHESTER
U.S. Forest Service
Murphy, North Carolina

Abstract

One of the most destructive seed insects of Eastern white pine (Pinus strobus) is the white pine cone beetle (Conophthorus coniperda). This pest can destroy entire seed crops. Early spring prescribed fire controlled this beetle in a North Carolina seed orchard, at considerably less cost than alternative chemical methods. Some seed trees were damaged but none have died. Pertinent life-cycle aspects of the beetle, level of control achieved, and fire behavior and effects are discussed. Preliminary operational guidelines for using prescribed fire to control the white pine cone beetle are presented.

Résumé

Les scolytes des cônes du pin blanc (Conopthorus coniperda) est l'un des insectes le plus destructeur des graines du pin blanc de l'est (Pinus strobus). Ce ravageur peut détruire des récoltes entières de graines. Un brûlage dirigé effectué au début du printemps a réussi à réprimer ce ravageur dans un verger à graines de la Caroline du Nord et a permis de réaliser des économies considérables comparativement aux autres méthodes de lutte chimique utilisées. Certains semenciers ont subi des dégâts mais aucun d'eux n'est mort. Certains aspects pertinents du cycle évolutif de ce coléoptère sont examinés ainsi que le degré de répression atteint et le comportement et les effets du feu. Des directives opérationnelles préliminaires sur l'utilisation du brûlage dirigé pour lutter contre le scolyte des cônes du pin blanc sont présentées.

Introduction

The white pine cone beetle (WPCB), Conophthorus coniperda (Schwarz) is the most damaging seed and cone insect of eastern white pine (Pinus strobus L.). In seed orchards, the loss of genetically improved seed can be particularly devastating. A worst case example was found in a 1988 damage survey of an Ohio seed orchard where the entire 1988 cone crop and over 90 percent of the 1989 cone crop (conelets) had been destroyed and the terminal shoots (the 1990 cone crop) were under attack by the WPCB (Barber, unpublished data).

Presented at the 10th Conference on Fire and Forest Meteorology, April 17-21, 1989, Ottawa, Canada.

The only effective insecticide is the systemic, carbofuran (Furadan[R]) (DeBarr et al. 1982). Over the past decade, a single winter application of this chemical has satisfactorily controlled the insect on the 26 ha white pine planting at the U.S. Forest Service Beech Creek Seed Orchard near Murphy, North Carolina. However, the recommended dosage is proportional to tree diameter, so the amount needed, and thus costs, escalate as trees grow. Furthermore, below-normal rainfall from January through early April is thought to limit insecticide uptake and translocation. Western North Carolina has been in a severe drought since 1984. The precipitation shortfall is about 1.8 m for the period 1984-1988 according to Wayne Swank (personal communication) of the Coweeta Hydrologic Laboratory, Franklin, NC.

Environmental concerns also continue to surface regarding this EPA approved chemical. Carbofuran was last applied at Beech Creek in 1985 at a cost of about $990 dollars per hectare. Approximately 11 ha were left untreated that year to assess the amount of beetle damage. On the untreated area, WPCB destroyed 92 percent of the seedcrop. This untenable level of damage prompted a reexamination of the beetle life cycle with an eye toward possible control options.

Adult WPCB overwinter on the ground in fallen cones (ODell and Godwin 1964). They emerge in the spring and fly into nearby white pines where they attack developing cones. They lay eggs as they proceed through several cones by early summer. Infested cones die and most fall to the ground unopened. The larvae feed on seeds and interior tissues of these dead cones. There is only one generation per year.

The WPCB thus spends 9-10 months of the year in fairly small dead cones in the litter beneath its host tree-- a habit that suggests prescribed fire as an effective control mechanism. Additional elements that allude to the potential of fire include: (1) short-term exposure to temperatures of 40-50°C is lethal to most insects, including the WPCB, and (2) seed orchards are routinely mowed to reduce fuel buildup and facilitate movement and seed collection.

USE OF FIRE TO CONTROL RELATED SPECIES

Mellish (1987) and Miller (1978) described the use of prescribed fire to control a related pest, the red pine cone beetle, C. resinosae Hopkins, in red pine (P. resinosa Ait.). There are, however, several important differences between the situation reported in Miller's work and the one encountered at Beech Creek. First, Miller used fire in natural stands that had been thinned to serve as seed production areas, whereas at Beech Creek the trees are all grafts and thus considerably more valuable. Second, red pine is much more fire resistant than white pine when mature (Wilson and McQuilkin 1969). According to Van Wagner (1970), both red and white pines are very susceptible to bole damage until the trees approach 30 cm. d.b.h. On the ramets at Beech Creek, graft unions are generally within one-third of a meter above ground. The bark above the grafts will remain thin, even after the trees attain considerable girth. Third, unlike the red pine seed production areas Miller studied, the Beech Creek seed orchard in the Southern Appalachians is on 30 percent slopes. The uphill sides of trees are much closer to the ground, and thus nearer a fire than would be the case on level ground. Finally, the red pine cone beetle overwinters in abscised vegetative buds while the WPCB overwinters in cones, which might provide more protection from fire.

The buds of both red pine and white pine are preset, which means that once the spring flush takes place, another flush will not take place until the following spring. Numerous studies have shown that complete defoliation during the summer usually results in death (Kulman 1965). Nonetheless, it was decided to attempt control of the WPCB with prescribed fire of very low intensity.

1987 Pilot Burn

The test was conducted on a 1 ha block containing about 150 trees. The ramets were 20 years old and averaged about 28 cm d.b.h. and 13 m in height. An adjacent area containing the same number of trees and a similar clonal layout was selected to serve as a check plot. Herbicide (Roundup[R]) had been used throughout the orchard in 1986 to control vegetation in a strip about 3 m wide within each row of trees. The heavy fescue sod between the rows had been mowed during the fall of 1986, but by March 6, 1987, the day of the burn, the succulent regrowth was about 13 cm tall. On the morning of the burn, the litter was raked back about 1 m from around each tree bole, exposing mineral soil. The debris was scattered to minimize the possibility of hot spots. The litter was raked from around only half the bole on 15 trees to evaluate this procedure.

Weather data were automatically recorded at the permanent weather station at the orchard office located within 1 km of the burn and at approximately the same elevation. The plot was ignited from a wetline at 12 noon, and burnout occurred about 45 minutes later. Burning conditions were: drybulb temperature 12°C, relative humidity 25 percent, and wind velocity SE at 5 km/h gusting to 10 km/h. The last recorded precipitation was 44.5 mm on Feb. 28 (7 days prior to the burn).

Fire damage to the seed trees appeared minor. Needles on one or more low branches on 15-20 trees were scorched but the buds were not damaged so the branches all refoliated. Pitch on the boles of 2 trees that had not been raked on one side caught fire but was quickly extinguished. All trees looked healthy the following spring.

WPCB mortality results exceeded expectations. Some infested cones were charred throughout, some partially charred, and some just scorched, but it made no difference. All beetles perished except for one sample of artificially placed cones that were extremely wet (moisture content 198% compared to the average of about 65%) in which 5 of 111 beetles survived.

1988 Operational Burn

BURNING PROCEDURES

The 1987 burn demonstrated the potential of fire to safely control the WPCB in eastern white pine. But questions remained regarding the practicality and costs of operational-size fires. The conelets present in the summer of 1987 suggested a bumper seed crop in 1988. The decision was thus reached to burn the full 26 ha planting of white pine in the orchard in the spring of

1988, including the 1 ha burned in 1987. The planting was comprised of 3 areas, each from a different seed source, and separated from one another by other species of seed orchard trees, or by oak-dominated hardwood forest. Because of the large investment tied up in each tree, there was little margin for error -- safety of the trees was paramount, but no guidelines existed except for the experience gained from the previous year. Moreover, the period between snowmelt and beetle emergence is fairly short and characterized by wide swings in the weather. Because the steep terrain was conducive to erosion, no permanent firelines were constructed.

The lower two whorls of branches were pruned from the white pines on all three areas during the fall of 1987 and the debris removed. Pruning left the pines with a clear bole up to about 2.5 meters and increased the distance between the ground and crown, thereby decreasing the chance of crown scorch during the burns. However, many of the pruning cuts bled profusely, resulting in a heavy flow of resin down the tree stems. The litter was raked from around each tree bole out to about a 1 m radius to help protect the tree stems and to reduce the chance of igniting these resin flows. Although the 1987 pilot burn showed that very little of the 2750 kg/ha litter (L) layer had to be consumed to achieve good WPCB control, increased forest floor consumption would not be harmful to the trees as long as the 15,000 kg/ha duff (F plus H layer) was damp enough to limit consumption of that layer.

A dry cold front passed through the area on Feb 29, and the decision was made to begin burning the following day even though the forecast predicted a very low minimum relative humidity. As long as the lower duff remained too wet to burn, the major concern about low humidity was from a fire control standpoint. If we saw that too much of the litter layer was being consumed as the humidity dropped during the day, or if easy control of the fire became questionable, the fire could be extinguished by one of the two tractor-mounted sprayers routinely used in the orchard or by a U.S. Forest Service pumper, all on site during the burn.

At 1030 hours on March 1, 1988, the first fire was ignited from a wetline along the highest edge of the area and allowed to back downhill past the first row of trees, and then across about 5 to 6 meters (rows were 9 m apart) of grass before reaching the heavy litter associated with the next downhill row of trees. Downhill rates of spread were predictably slow (roughly 20 m/h), and various modifications in the ignition plan were tested to find a procedure that would result in a faster burnout time without unduly increasing the potential of tree damage. Personnel patrolling the fire front with 19-liter backpack pumps to wet down resinous tree boles that appeared to be getting too hot (in fact several did ignite before being extinguished) were kept busy until an efficient firing pattern was developed. This pattern entailed ignition of the upper side of the area, letting the fire back down past the uppermost row of trees into the grass median between tree rows, then igniting the bottom of that grass strip. The upper edge of this second fire would head across the grass and meet the fire backing downhill while the lower edge would itself back downhill past the second row of trees. This process was repeated until the bottom side of the area was fired. Personnel with backpack pumps soon learned to anticipate potential problem trees and wet down the boles before the fire front arrived. Damage to individual tree crowns was generally minor (less than 10 percent) except in the draws, where convective heat was channeled. Crown damage was more extensive on trees in draws; the foliage on some was almost completely scorched.

Many of the mature open cones (moisture content 9%) were consumed, but the closed immature cones (moisture content 12%) containing the beetles were not. Moisture content of the cured grass and "L" layer averaged 13 percent at ignition, dropped to 8 percent by 1400 hours and recovered to 13 percent by 1845 hours. Duff moisture ranged from 16 to 33 percent. Much of the litter layer was consumed, but the duff layer remained to insulate the soil and tree roots. Some problems were experienced within the 1-m raked circles. Many eastern white pine roots were exposed when the litter was raked from around the trees. Because these large roots were at the surface, it was difficult to remove the duff. Raking was done several days prior to the burn, giving any remaining duff time to dry out. If these inter-root patches of duff were not wet-down before being reached by the fire front, they invariably ignited.

Flame lengths of backing fires averaged 0.15 to 0.25 m, and headfires 0.3 to 0.5 m. Backing fire flame zone width was less than 3 cm. The fire front backing downhill could not preheat fuels on these steep slopes, whereas the flame envelope moving uphill was close to the ground and preheated fuels ahead of it. Headfire flame zone width averaged 0.06 to 0.6 m, depending upon windspeed. Wind gusts frequently tilted the flames enough to make contact with the unburned fuel, causing ignition 0.4 to 0.6 m at a time rather than as a steady progression upslope. This process strongly influenced headfire rates of spread, which ranged from 0.36 to over 1.2 km/h. Fireline intensity also varied widely from about 100 to 850 kW/m. Flame residence time averaged about 7 to 9 seconds regardless of fire type. Burnout on the first area occurred at about 1245 hours. By this time the RH had dropped below 20 percent but no control problems were noted. About 90 percent of the area burned. Spotting was not a problem and no containment problems were encountered, primarily because of the light fuel loads between the tree rows.

The second area was ignited at 1400 hours using the procedure perfected earlier in the day. Much less crown scorch was incurred. Some of the duff remaining between tree roots in the raked circles was removed just prior to ignition of the area to eliminate this source of potential damage. Four of the 8 blocks in this second area were left unburned to serve as a control. Relative humidity reached a minimum of 14 percent and drybulb temperature peaked at 14°C at about 1530 hours. Fire behavior parameters increased slightly. Backing fire rate of spread increased to about 26 m/h and residence time decreased to 5 to 6 seconds. Average headfire rates of spread ranged from 0.22 to 0.3 km/h when flame contact did not occur and upwards of 1.1 km/h when flame contact took place. Maximum average flame length increased to 0.5 m for backing fires and 0.8 m for heading fires. Fuel consumption increased to over 50 percent and some infested cones were partially consumed. This area contained the plot burned the previous spring. Although litter fuels were very light, the herbaceous cover was complete and carried the fire well. Burnout of the last block on the second area was complete by 1930 hours.

The final area was ignited at 1015 hours the next day. Drybulb temperature reached 20°C and the relative humidity again dropped below 20 percent. Fire behavior was essentially the same as the previous day. Little crown scorch was noted but some tree boles ignited, primarily because an attempt was made to burn off several spur ridges at the same time resulting in too many lines of fire for the people with backpack pumps to effectively monitor.

TREE DAMAGE

Four weeks after the fires, a damage survey was conducted and trees on the first two areas placed in one of 4 crown scorch classes. Forty-nine trees on Area 1 and 6 on Area 2 were severely scorched (over 33 percent crown scorch), but all leafed out during spring flush. Most of the trees in this scorch class had less than 50 percent crown scorch, but even the 3 that lost more than 80 percent of their foliage survived. The moderate scorch class (10 to 33 percent) contained 94 and 32 trees on Areas 1 and 2, respectively. Seventy-eight trees on Area 2 suffered 1 to 10 percent crown scorch as did several hundred on Area 1. A total of 335 trees on the Area 2 burns were unscorched. Crown scorch on Area 3 trees was not mapped because a cursory survey turned up only a few trees in the moderate scorch class and none in the severe scorch class. One year after burning, scorched trees throughout the orchard appeared just as healthy as unscorched trees, except that their crowns looked thinner because the branches with heat-killed foliage contained only 1-year-old needles. Since the buds of eastern white pine are preformed, prescribed burns should be conducted before the spring flush. Otherwise, extensive scorch is likely to cause mortality.

Inspection of the trees 1 year after burning showed many had large patches of discolored (brown) surface bark which appeared to be dead. These patches were primarily on the uphill side and ranged from about 0.5 to 4 m above ground (precisely where heat from a fire would be concentrated). Discolored patches were also found on trees in the unburned blocks, but not as many of them. When heavily pruned, eastern white pine is prone to sunscald which could account for much of the damage. In addition, a mechanical tree shaker has been used for the past 5 years to dislodge seeds.

S. Oak (personal communication), U.S. Forest Service plant pathologist, believes that these discolored patches are simply a result of natural bark maturation, which begins first on the sides of the trees that are exposed to higher temperatures and drying by solar radiation. Pruning and burning simply accelerated the process. However, subsequent to this analysis, reference to fire-caused eastern white pine cambial injury was found in the literature (Olson and Weyrick 1987). Their research, based on several dozen fires over the past 15 years, shows heat injury is indicated by "...rusty red color and soft spongy feeling on the outer bark. If this red color completely encircles the stem, the tree will die." Some of the trees at Beech Creek are almost encircled and although they looked healthy 12 months after the March 1988 fires, the demands of bud break and foliage production this spring should determine the fate of these trees.

WPCB CONTROL

Analysis of cones collected before and after the burn showed that beetle populations had been decimated on all three areas. Nonetheless, the WPCB killed 66 percent of the cones on Area 1 in 1988. About twice as many cones were found to be beetle-killed on the unburned portion of Area 2 as on the burned portion. On Area 3, roughly 10 percent of the cones were attacked during the spring of 1988.

Several hypothese were developed to explain this cone mortality in light of the high level of WPCB control achieved on the burns. Nets are used to collect the seed crop each fall and infested cones are simply discarded at the edge of the area. Reexamination revealed that many of these piles of cones in Area 1 did not show any signs of scorch. The fire never reached these piles, apparently because the wetline was located uphill of them. In addition, a high beetle population exists in the naturally occurring eastern white pine adjacent to the orchard. These sources of beetles along with beetles in the unburned half of Area 2 were likely causes of the high incidence of attack in the burned areas. In spite of these losses, 1988 yielded a bumper crop of seed. Over 90 kg/ha were collected -- enough to meet the expected demand for the next 2 to 3 years.

Preliminary Prescribed Fire Guidelines

The first 2 years of burning have been a learning experience for all involved. The following guidelines have emerged from this field study for conducting future burns under eastern white pine ramets in the Beech Creek Seed Orchard.

1. Do not burn under conditions as severe as those used in 1988. Fire control was not a problem and the

pines apparently escaped serious damage, but less intense fires would have done just as good a job.

2. Burn all eastern white pine areas between snowmelt and at least 2 weeks prior to beetle emergence, which usually occurs about April 1st. Once greenup occurs, it becomes more difficult to back fires through the grass.

3. Rake the litter from a 1 m radius circle around each tree and off of exposed roots. Rake just prior to burning so any duff remaining inside the circle will not have the opportunity to dry out.

4. Use wetlines and not plowlines as firebreaks.

5. Begin burning in the morning as soon as, but not before, any dew or frost has evaporated. Shaded areas not yet reached by the sun may not burn. It is important that the fire covers the full area so all cones are heated.

6. Ignite the upper boundary with a line fire so that it backs downhill past the first row of trees. When the fire is 1 to 1.5 m past this first row, the torch person can bring the flank downhill along a wetline, make a 90 degree turn and string fire across the area several feet upslope of the second row of trees. This fire will head uphill to meet the initial backing fire and back downslope past the second row of trees. The process is continued until the lower boundary of the area is reached.

7. A wide range of weather conditions can be tolerated. Preferred conditions include adequate soil moisture (Keetch-Byram Drought Index below 250), fine-fuel moisture content between 8 and 20 percent, infested cone moisture content less than 65 percent, relative humidity 20 to 50 percent, and drybulb temperature below 15°C.

8. Low windspeed from a single direction would be ideal. Variable winds up to perhaps 5 to 6 m/sec can be easily accommodated as long as the burning boss makes appropriate adjustments in firing technique. Windspeed across ridgetops will likely exceed the 6 m windspeed registered at the orchard office weather station.

9. Complete consumption of the litter layer is a strong indicator that the fire should be extinguished. WPCB's will be killed by very low intensity fires unless the infested cones have an unusually high moisture content. The cones do not have to be consumed, simply scorching them will raise internal temperatures past the lethal threshold.

10. Both tractor-pulled and truck-mounted sprayers proved very effective. Foam is not necessary.

11. Backpack sprayers should be mandatory! Wetting tree boles is tiring but essential work. Individuals must be in excellent physical condition and self motivated to be most effective. The best policy would be to wet down each tree bole and all exposed roots in the cleared circle just prior to arrival of the fire front, rather than waiting to see if the resin or remaining duff catches fire and then trying to get close enough to extinguish the flames.

12. Whenever a line of fire is ignited across a draw, this topographic feature will act as a chimney to concentrate and channel heat up the draw. Any trees in the draw will thus have a much higher potential of being crown scorched.

13. These burns should have a minimal impact on air quality because of the light fuel loadings and lack of smoldering combustion.

Summary

The white pine cone beetle is one of the most destructive seed and cone insects in North America. It is not unusual to lose the complete eastern white pine seed crop to this pest. The systemic insecticide carbofuran effectively controlled this beetle on the Beech Creek Seed Orchard in western North Carolina until 1984, but thereafter its usefulness was drastically curtailed by costs and severe drought conditions. This prompted the "last resort" decision to use fire. When planning the first trial burn, no guidelines existed. Based on the literature, we were braced for the distinct possibility of severe tree damage including some mortality.

The gamble paid off. Even the few trees that suffered over 50 percent crown scorch appeared healthy 1 year after burning. We demonstrated that WPCB populations can be significantly reduced at a cost less than one tenth that of chemical control. We believe even higher levels of control can be achieved by making sure all infested cones are included in the areas to be burned.

References

DEBARR, G.L., L.R. BARBER, AND A.H. MAXWELL. 1982. Use of carbofuran for control of eastern white pine cone and seed insects. Forest Ecology and Management 4:1-18.

KULMAN, H.M. 1965. Effects of artificial defoliation of pine on subsequent shoot and needle growth. Forest Science 11(1):90-98.

MELLISH, S.B. 1987. The use of prescribed fire for control of the red pine cone beetle, (Conopthorus resinosae Hopkins) (Coleoptera:Scolytidae) in a New Brunswick red pine (Pinus resinosa Aiton) seed production area. M.S. Thesis, Univ. of New Brunswick, 120 pp.

MILLER, W.E. 1978. Use of prescribed burning in seed production areas to control red pine cone beetle. Environmental Entomology 7(5):698-702.

ODELL, T.M. AND P.A. GODWIN. 1964. White-pine cone beetle. USDA For. Pest Leafl. 83, 7 pp.

OLSON, D.P. AND R.R. WEYRICK. 1987. White pine management with prescribed fire. New Hampshire Agricultural Experiment Station Research Report Number 113. 15p. New Hampshire Agricultural Experiment Station, University of New Hampshire, Durham, NH

VAN WAGNER, C.E. 1970. Fire and red pine. Proceedings 10th Annual Tall Timbers Fire Ecology Conference. Fredericton, New Brunswick. August 20-21, 1970. p.211-219.

WILSON, R.W. JR., AND W.E. MCQUILKIN. 1969. Silvicultural characteristics of eastern white pine. USDA Forest Service Research Paper NE-13. 29p. Northeastern Forest Experiment Station, Broomall, PA.